

ART. II.—*Papuan Timbers.*

SOME OF THE PROPERTIES OF SIX SPECIES.

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(With Plates X.-XX.).

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Introduction.

The investigation of the timber resources of Papua was placed in the hands of Mr. Gilbert Burnett, District Forest Inspector of the State of Queensland, by the Commonwealth Government of Australia, in the year 1908. He reported on 123 species after visiting eight important districts. His report was printed by the Government printer and issued by the Department of External Affairs, Melbourne.

In his report he says:—"The names of the different varieties are such as have been supplied to me by those of the natives of the various localities who appeared to possess the largest amount of knowledge of the native woods; and the greatest care has been exercised in noting them correctly."¹

Under these conditions, it is highly probable that some confusion may exist, as several names are given to the one variety of tree, these being the names given by the most intelligent natives in the several districts in which the trees grow. Thus, if there are twenty districts, there may be twenty different native names. In a territory such as Papua, where there is no written language and a great number of dialects, it may be necessary to record all names, but if the meaning of each of these words were ascertained and that meaning described the particular genus, some such colloquial name might be adopted.

¹ Timber Trees of the Territory of Papua: Reports and Catalogue. By Gilbert Burnett.

It is to be regretted that botanical specimens were not procured at the same time, submitted to one of Australia's eminent botanists and placed on record for reference, thus placing in the hands of those seeking reliable information a ready means of identifying the various species in the several districts. Another source of confusion is likely to arise, through the way in which a word describing a tree is spelt. As with children so with most of the island natives the letter R is a great difficulty, and L is nearly always substituted, hence *Aruru* may become *Alulu*, *Aragu*, *Alaga*, etc. This has already occurred in two out of the six species which are referred to in the following pages.

The author is not aware that any serious attempt has been made so far to collect and classify the flora of Papua, but it is known that while the great majority of the flora is peculiar to Papua, there are representatives of the mainland also growing there.

In fulfilment of a promise by the Secretary for External Affairs, the author received six species of Papuan woods upon the understanding that they should be submitted to the usual mechanical tests and a report furnished. The colloquial names supplied with the specimens were *Ulabo*, *Alaga*, *Tamonau*, *Kokoila*, *Maduve* and *Ilimo*. With the exception of the first two, the spelling used by Mr. Burnett has been adopted. In the case of the two mentioned, it is possible that the spelling of one or other of the authorities may be incorrect, but from the description in the Catalogue, they evidently apply to *Uraba* and *Aragu*.

All the specimens were of fair quality, more or less seasoned, and measured nine feet long by six inches wide and four inches deep. With the exception of *Maduve* (only one piece being sent), two pieces of each were forwarded. These were cut to lengths of four feet six inches, and subjected to the cross-breaking test, after which they were cut up into specimens for end-grain compression, tension, shearing, bending, charcoal and ash tests. The percentage of moisture in each tested specimen was ascertained, and the change in colour due to heating noted, and also the amount of moisture reabsorbed after drying.

The weights per cubic foot were calculated from the dimen-

sions and weights of the specimens, after they had been planed on an ordinary wood planer. The dry weights were calculated from the moisture percentage experiments. The weight of the seasoned wood was calculated from the observations taken on reabsorption. This weight will vary with the hygroscopic state of the atmosphere.

As this is the first time these timbers have been subjected to mechanical tests, it will be well to treat them rather fully.

Description of the Specimens.

In describing the general appearance of the specimens, the first name will always be that supplied by the Department of External Affairs, and the second the name given to the species by Mr. Burnett.

Ulabo (Afzelia bijuga).—Urabo of the Eastern Division. It is common throughout coastal Papua, and consequently has several different names as follow:—Melila and Mokaika, at Motu; Pida at Vailala; Uio in Western District; Kurabi, North and Eastern Divisions; Bendora, Northern Division.

The specimens received varied slightly in colour, one being fairly dark, somewhat like the dark Tasmanian and Victorian blackwood, but not so rich in colours; heavy, close grained, yellowish brown when freshly planed, but darkening on exposure to the light, of an oily nature, easy to work, and should take a fine polish; if either shavings or sawdust, taken from this wood, be boiled in water for fifteen minutes and the liquid evaporated, a dark shellac-like substance is left, which may be of economic value. Some of the pores contain a yellow sulphur-like material, which came away as fine dust during the cross-breaking tests. Evidently a strong, durable wood; it has been proved to be absolutely proof against white ants, but it will not resist the teredo.

Alaga.—Araga (Fam. Sapotaceae), from the Eastern Division. Being common throughout Coastal Papua, it too has several local names—Ohabu, Vailala; Borua (probably Bolua), Northern Division; Ediua, Kemp Welch; and Koiua, Buna Bay.

The specimens are of a reddish, light brown colour, the sapwood a light bluff. The grain is fairly close and straight. It

should be a good wood for joinery and general inside purposes. For boat building, coach and carriage building, it ought to be excellent. It appears to be a fairly durable wood.

Tamonau.—Tamanau (no botanical name) of the Eastern Division; Dandigo, of Buna Bay. Very light medium grained wood, with no particular figure. Light pink or nearly buff in colour, in some lights there is a satin-like sheen and bluish streaks in some of the annual rings. It has not the appearance of a durable timber, being totally unfit for use in damp situations. In one part of the specimen, where it had evidently been on the ground, signs of decay were apparent. It is easy to work, and finishes under the planer with a woolly surface; for light inside work it should be very serviceable.

Kokoila.—Kokoilo (*Calophyllum inophyllum*) Eastern Division; Oma, Vailala District. Light, cedarlike, open-grained wood, rather a pretty figure (reminding one of cocoanut wood), brownish red in appearance, slightly attacked by a small borer or worm, would not be durable in damp situations, but would be useful for panels as a substitute for cedar. The openness of the grain, either straight from the saw or under the planer, would suggest a great amount of "filling" before polishing, but when properly sandpapered the finish is very fine and the grain seems to be close.

Madave.—Madave, of the Sagarai Valley; "This seems to have affinities with *Shorea Dipterocarpeae*" (J. H. Maiden). One of Vailala. Light, cedar-like, open-grained timber. The colour is a shade lighter than Kokoilo, but the figure is not so pronounced. It is coarse-grained, easy to work if planed in the direction in which the rings run out, otherwise broad, rough bands are produced. It has the appearance of a brittle timber. It should be useful for joinery where light work is required, especially for cabinet work. It does not give one the impression of being a durable timber in damp places.

Ilimo.—Ilimo, of Motu, (order *Bignoniaceae*) found in Laloki and Brown River Districts. Iloea, Vailala; Binumba, Cape Nelson and Buna Bay; Kiua, Cape Vogel.

This was the lightest timber received, both in colour and weight, soft, fairly close-grained; when viewed by reflected light on the "quartered" side, it has the appearance of grey

satin, on the "backed" side, the appearance is an alternate dark and light grey. Figure somewhat like cedar. It should be a fair wood for light work of any description where it can be kept dry, as it takes up moisture very quickly. After being planed, the surface took on a yellowish green tinge, which nearly disappeared after standing in the air for a few days. It is easily worked on the "backed" side, but on the "quartered" face rough bands appear, as in *Kokoilo* and *Madave*. (See photographs of fractures).

Weight per Cubic Foot and Moisture Percentage.

All timber contains moisture, either as liquid in the cells or moisture in the cell walls. The free liquid drains from the wood in a comparatively short time, reducing the apparent weight as much as twenty-five per cent. in a few weeks, but it takes much longer to evaporate from the cell walls.

Timber is never absolutely dry unless it is submitted to a continuous heat sufficiently intense to drive off all the moisture. The changes which take place in the wood, during this drying process, may be chemical or simply drying due to evaporation; in the same way celluloid, glue and albumen occupy a much larger space when moist than when dry. The three examples quoted illustrate fairly the state of the cell walls before seasoning or drying. Before drying, the cell walls are thick, after they are thin, that is, a circular, oval or polygonal cell wall may be when wet or unseasoned comparatively thick, and the pores or cells comparatively small, but when dry, or nearly dry or seasoned, the cell walls have shrunk and become thinner and the pores larger, but the space occupied by a certain area of the seasoned wood is not so great as that of the unseasoned, otherwise there would be no shrinkage, only loss of weight. Matured wood shrinks much less than semi-matured, and semi-matured less than young saplings. Hence in the wood of a sapling, large checks appear, in semi-matured wood smaller, and in matured wood only small checks are discernible. The various stages can be readily traced in beams cut from different parts of trees, but far more easily from young, semi-matured and matured logs.

In the first case, "heart shake" of a very pronounced character is nearly always developed, in the second case "star," and to a certain extent "cup shake" occurs, but in matured wood the pith has generally begun to decay and the moisture is being evaporated both from the inside and the outside, and if seasoning checks do occur, they are in the form of small cracks, which close up when the process is complete. Also, it is almost a rule that the heavy dense woods contain the least moisture and the more open grained and lighter ones contain the most.

In these experiments, the dry weight of the several species was obtained by weighing one hundred grains of borings, taken from near the fracture, immediately after the specimen had been tested. The borings were then placed in an oven, which was kept for forty-eight hours and upwards, at a temperature of 103 deg. C., kept there in fact until the weight ceased to decrease. The loss of weight was thus directly found, and the percentage of moisture accurately ascertained. Having obtained the percentage of moisture in the timber, and having previously ascertained the weight per cubic foot, it was easy to calculate the "dry weight."

That timber "comes and goes," or expands and shrinks with the weather, can be verified during wet and dry seasons, when many instances come under casual observation; hence the expulsion of moisture decreases the weight of timber, and such weight varies with the proportion of moisture it contains. In the following table (Table 1) the percentage of moisture reabsorbed was ascertained after allowing the dry borings, already mentioned, to stand in the atmosphere for at least seven days. During that time the thermometer never rose above 73 deg. F., but the hygroscopic state of the atmosphere varied. The results prove that timber, air dried, always contains a certain amount of moisture, so that naturally-seasoned timber must always contain moisture, and kiln-dried wood will take up moisture until it reabsorbs within two per cent. of the naturally seasoned wood. The fourth column in the table will therefore give the limit, which the degree of moisture in naturally-seasoned timber of these varieties may be expected to attain in practice.

TABLE 1.

MEAN WEIGHTS PER CUBIC FOOT AND MOISTURE PERCENTAGES.

Name of Timber.	Weight per c. ft. when tested (lbs.)	Moisture p. c.	Weight per c. ft. of dry wood (lbs.)	Percentage of moisture re-absorbed	Weight per c. ft. of seasoned wood (lbs.)
Ulabo	67.47	21.6	42.90	11.00	58.70
Alaga	42.10	16.4	35.20	12.00	39.40
Kokoilo	40.20	13.0	34.97	10.30	38.57
Madave	37.15	14.4	31.80	11.50	35.45
Tamanau	30.40	13.0	26.44	11.00	29.35
Ilimo	30.90	32.8	20.80	11.00	23.08

Change of Colour during Drying.

During the drying operation all the borings changed colour.

Ulabo changed from a yellowish brown to a bluish chocolate.

Alaga, from a pinkish brown to a deeper shade.

Kokoilo, to a purplish brown.

Madave, to a decided brown.

Tamanau, to a light brown: and

Ilimo, to a rather duller grey with a yellowish tinge.

Bending Experiments.

A series of six pieces from each of the varieties was submitted to a severe bending test. The apparatus, designed by the author and used for these tests, is illustrated in Fig. 1, Plate X.

A, is the steaming chamber. B, the boiler. C, condenser. F, funnel for filling the boiler. H, the steam pipe leading to the steam chamber from the boiler. T', the thermometer to watch the rise of temperature in the chamber. T, the tube around which the specimen is to be bent. W, the weight of ten pounds. P, a pointer, which is attached to the weight at right angles, so that it is always horizontal. J, a jockey clip which is bored for a pin to carry the weight. The clip is attached to a piece of spring brass which rests on the specimen when being bent. S is the specimen, and a is the angle iron under which one end

of the specimen is placed. I is the glass front. The whole of the chamber is covered with half-inch felt. The boiler is heated by gas, and the steam in the chamber can be raised to boiling point. By attaching a metal coil to the steam inlet and condenser, the apparatus can be converted into a drying chamber.

The specimens were twenty-two inches long, three-quarters of an inch wide, and three-eighths of an inch deep. A band of spring brass was attached to a brass jockey clip, through which a hole was drilled, so that a brass pin could be inserted in order to carry a casting of lead weighing 10 lbs., to which a horizontal pointer was attached. The specimen was placed under the band, and the whole inserted in the chamber preparatory to steam being turned on. The end opposite to the weight was placed under a piece of angle-iron which is riveted to the end of the steaming chamber. Nine inches from the angle-iron a galvanised iron pipe, two and three-eighths of an inch in diameter, was placed. The specimen rested on the pipe, and the weight was allowed to act during the whole of the steaming process. All the specimens were subjected to the same weight under similar conditions. Each variety of timber was so arranged that two were tested with the annual rings parallel to the direction of bending, two at right angles and two with the rings diagonal. All were placed in the chamber at the temperature of the surrounding atmosphere, which averaged 73 deg. F. The chamber was then closed and steam admitted, and through the plate glass front of the chamber the relative bending of the specimens could be noted from time to time.

Under these conditions, *Ulabo* is undoubtedly the best bending timber, as the whole six bent over the pipe without the least sign of stress on either the compression or tension sides.

Kokoilo came next, with three out of the six bending.

No. 1, being cross-grained, showed a split on the tension side in the direction of the uneven grain. Rings diagonal.

No. 2 was very much stressed and broke with slight pressure. Rings parallel.

No. 3 bent, with slight flaking on tension side. Rings vertical.

No. 4 good bend, but slight twist (twisted grain); no fracture. Rings diagonal.

No. 5 good bend, straight grain. Rings parallel.

No. 6 broke short at the bend. Rings vertical.

Alaga.—All the specimens of *Alaga* broke, but four of them bent to an angle of 45 deg. before breaking, leaving a fair permanent bend away from the fracture.

Madave.—All the specimens bent to an angle of 30 deg., then broke. Slight permanent bend in four of them.

Tamanau.—No. 1, which was a diagonal specimen, bent well, but split on the tension side; the others broke without permanent bend.

Ilimo.—Four of the specimens broke before the steam was applied, the other two took on a permanent "set" of about 15 deg. after remaining without steam for twenty-four hours. In this case the three-quarters by three-eighths pieces were replaced by specimens three-quarters of an inch square, and were steamed for five hours. After steaming for an hour and three-quarters, No. 5, which was a diagonal-ringed piece, broke, No. 6, a similar piece, bent most, the other four remaining at an angle of about 15 deg. With the exception of this set, none of the specimens required steaming for more than fifteen minutes.

Under these severe conditions the six varieties may be classed for bending as follows:—

Ulabo	-	Excellent.
Kokoilo	-	Good.
Alaga	-	Fair.
Madave	-	Moderate.
Tamanau	-	Bad.
Ilimo	-	Bad.

Other Mechanical Tests.

The examination of timbers as to their adaptability for economic purposes requires that they should be submitted to several tests. For instance, timber for engineering purposes should be strong and durable; for architecture it should be strong, durable, comparatively light, with variety in figure, capable of undergoing certain treatment such as bending, polishing and glueing, and of resisting splitting when either nailed or screwed; excessive expansion and contraction during at-

mospheric changes is very objectionable. For gunstocks, it should be comparatively light, and capable of taking wood or iron screws without tearing; when exposed to wet it should not become rough or woolly, it should clean up well when carved or machined, be close grained and of rather a "cheesy" nature but hard enough to resist ordinary wear and tear without "denting." To a certain extent it should have a good figure, but expansion or contraction is fatal; for most of the minor uses, bending is one of the qualities required.

In investigating the value of the six Papuan species, they have been subjected to the following mechanical tests:—

CROSSBREAKING OR BEAM TESTS.

All beam tests were made on a four foot span, but the effective span was 45.71 inches, due to the method adopted of applying the load. The central load was spread over a width of 2.29 inches by means of two swivel bearings. The span (the supports also being on swivel bearings) was 48 inches.

The formula for calculating the "modulus of rupture" was:—

$$F = \frac{3}{2} \times \frac{WL'}{bd^2}$$

Where W = total load required to break the specimen.

L' = the effective span. (Clear span minus the distance between the centres of the swivel bearings.)

b = the breadth of the test piece.

d = the depth of the test piece.

The "modulus of elasticity" was obtained by plotting, on squared paper (Fig. 2, Plate XI.), the readings taken on a specially designed "Deflectometer,"¹ (Fig. 3, Plate XII.). The formula used for obtaining the "modulus of elasticity" was:—

$$E = \frac{WL^3}{4bd^3\delta}$$

Where W = weight in pounds, producing deflection.

L = clear span (48 in.).

b = breadth of the test piece.

d = depth of the test piece.

δ = deflection produced by weight W.

¹ This instrument was designed by Professor H. Payne, and made by his assistant in the Engineering Laboratory. It was used for the first time during these tests, and was accurate throughout.

The following Table 2 gives the mean modulus of rupture and the mean modulus of elasticity of the six species, schedules of details being given subsequently:—

TABLE 2.

Name of Timbers.			F. in lbs per sq. in.		E. in lbs per sq. in.
Ulabo	..	...	16485	...	2084250
Tamanau	...	...	8637	...	1095200
Alaga	...	...	8185	...	1539500
Madave	...	...	6605	...	1081350
Kokoilo	...	...	5725	...	799675
Ilimo	...	...	4736	...	795900

COMPRESSION ALONG THE GRAIN OR COLUMN TESTS.

Specimens, cut from the beam tests, were subjected to compression along the grain tests, that is, as columns. The dimensions were approximately three inches square, the exact figures being given in the schedule of details. The length was twenty inches. The ratio would be nearly 1-7th, consequently they would be short columns, and should give the true compressive resistance of the material in this particular direction.

Strength in compression is a fair gauge of the relative quality of timber for general work, but does not represent its usefulness for special purposes, such as cabinet work, etc.

To ascertain the breaking weight per square inch, the total load producing fracture was divided by the area of the end grain thus W/DB = breaking weight in lbs per square inch, where W = total breaking weight or load.

B = breadth.

D = depth.

The following Table 3 shows the mean strength in compression of the six species:—

TABLE 3.

Name of Timber.					Mean breaking weight in lbs. per sq. inch.
Ulabo	-	-	-	-	9522
Alaga	-	-	-	-	6110
Madave	-	-	-	-	5760
Tamanau	-	-	-	-	5320
Kokoilo	-	-	-	-	4795
Ilimo	-	-	-	-	3550

TENSION TESTS.

Tension tests are not of very great value, as usually timber is stronger in tension than in any other direction, and would seldom fail under that stress while other portions of the same structure, constructed of the same wood and of the same dimensions, were directly under any of the other stresses. In very brittle timber, it might happen, but never in sound, fibrous wood. For comparison, however, it is well that these tests should be made.

The "tension" specimens were prepared in the lathe in the form shown in Fig. 4. The original dimensions were 20 inches long and $2\frac{1}{4}$ inches square. These were turned to a diameter of $\frac{3}{4}$ inch in the centre, parallel for eight inches between the shoulders. The portion to be gripped in the testing machine was $3\frac{1}{2}$ inches by 1 $\frac{3}{8}$ th inches diameter, the remainder being just cleaned up. The experiments and remarks are given in the schedule of details. The mean breaking strengths per square inch are given in Table 4.

TABLE 4.

Name of Timber.	-	-	-	Breaking weights.
Ulabo	-	-	-	15750
Alaga	-	-	-	14505
Tamanau	-	-	-	10795
Madave	-	-	-	5380
Ilimo	-	-	-	5300
Kokoilo	-	-	-	4960

SHEARING TESTS.

Specimens cut from the compression pieces were tested in shear. They were approximately three inches square and one and a-half inches deep, the depth being along the grain. They were tested in double shear. Half of the pieces were sheared parallel to the annual rings and the other half at right angles to them. The shearing strength was calculated by dividing the load producing shear by the area sheared. Thus—weight per square inch = Total load/2bd.

Thirty-two shearing tests were made, and the results show that when the plane of shear is parallel to the annual rings, all the fractures are fairly even, and in most cases, the same evenness appears when the plane of shear is at right angles to the rings, but in the case of *Kokoilo* and *Ilimo*, the fractures were very angular, and increased the area of shear from 50 per cent. to 75 per cent.

TABLE 5.

Name of timber.	-	-	-	Mean shearing strength.
Ulabo	-	-	-	2120
Kokoilo	-	-	-	2010
Madave	-	-	-	1810
Alaga	-	-	-	1670
Tamanau	-	-	-	1090
Ilimo	-	-	-	882

From the foregoing tables it will be seen that no definite proportion exists between the stresses of the same timber, but the timbers themselves vary a great deal in strength in their relations to each other. *Ulabo* stands out prominently as the stronger, the sum of the stresses being 43,877 pounds, *Alaga* coming next with 30,460 pounds; then *Tamanau* 25,742 pounds, *Madave* 19,555 pounds, *Kokoilo* 17,490 pounds, and *Ilimo* 14,468 pounds. From these figures it could be reasonably expected that *Ulabo* would be a good engineering timber, *Alaga* and *Tamanau* good woods for joinery and general work, and the remaining three—viz., *Madave*, *Kokoilo* and *Ilimo*—ought to be suitable for light joinery, cabinet work and furniture.

By referring to Table 1 it will also be noticed that the strength does not follow in the order of the weights.

Burning of Splinters.

In addition to the mechanical tests, the colour and quality of the ash produced from the burning of splinters was noted.

When complete combustion takes place, as in the ordinary fire stove or furnace, the ash is generally white or of a dirty greyish colour, while an ordinary wooden match always gives a brittle black ash. If pieces of wood in the form of splinters

be taken from the different species, lighted, and allowed to burn in still air, several peculiarities will be observed, which escape observation during ordinary combustion. Some woods burn readily until the whole splinter is consumed; others are difficult to burn; some crackle or splutter, while others burn quietly; again, some glow brightly, others burn dully; one will cease to glow as an ember immediately, another will continue to glow for several seconds, perhaps minutes; one will die out with a brilliant spark and another will die without a glow. The colour of the ash, too, will vary. Some species retain the ash as a short piece of brittle carbon, others retain it as a snow-like point; in others, nothing is left but a most delicate web-like fluff, while others again will leave a feathery substance, which floats away like down. As a means of identification, this property is an aid, and in order to give some idea of its value, is included in these investigations.

The following peculiarities have been noted during experiments on this series of Papuan woods:—

Name of Timber	Remarks on the character of the ash, etc.
Ulabo (<i>a</i>)	- Splinter burns fairly well, slowly, leaving a bluish-white ash, which is retained and feathery.
Ulabo (<i>b</i>)	- Splinter burns badly, leaving a bluish-white ash, which is retained and feathery.
Ulabo (<i>c</i>)	- Splinter burns slowly, leaving a bluish-white ash.
Ulabo (<i>d</i>)	- Splinter burns slowly, leaving a bluish-white ash.

[Note.—The spark smoulders for a considerable time; should make a splendid firewood when once lighted.]

Alaga (<i>a</i>)	- Splinter burns slowly and quietly, leaving a pure white feathery ash.
Alaga (<i>b</i>)	- Same as (<i>a</i>).
Alaga (<i>c</i>)	- Splinter burns with slight “crackles;” white ash
Alaga (<i>d</i>)	- Same as (<i>c</i>).

[Note.—(*c*) and (*d*) were lighter coloured woods than (*a*) and (*b*).]

Tamanau (<i>a</i>)	- Splinter burns badly, crackles; white ash, but grey or bluish at the spot where the spark dies.
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Tamanau (*b*) - Splinter burns badly, leaving a grey or bluish-white ash.

Tamanau (*c*) - Same as (*b*).

Tamanau (*d*) - Same as (*b*).

Madave (*a*) - Splinter burns slowly, rather badly, bluish-grey ash.

Madave (*b*) - Same as (*a*).

Kokoilo (*a*) - Splinter burns fairly well, leaving a pure white feathery ash, which is retained.

Kokoilo (*b*) - Splinter burns badly, ash as above.

Kokoilo (*c*) - Splinter burns slowly, ash as above.

Kokoilo (*d*) - Splinter burns slowly, ash as above.

Ilimo (*a*) - Splinter burns well, leaving a creamy-white ash, which is retained and feathery.

Ilimo (*b*) - Splinter burns well, but dully, ash as above.

Ilimo (*c*) - Splinter burns well, but quietly, ash as above.

Ilimo (*d*) - Splinter burns well, but quietly, ash as above.

From the above observations, it would appear that all the varieties are fairly rich in potash, but this can only be definitely ascertained by chemical analysis.

Charcoal Properties.

Six cubes of each kind of timber were subjected to a "carbonising process," in order to ascertain their charcoal properties. Each cube was accurately weighed and then placed in an oven, which was surrounded by a bath of ordinary machine oil. The temperature to which the oil could be raised safely had been previously ascertained, and was found to be above 160 deg. C. The cubes were placed in the oven and kept for twenty hours at a temperature of 105 deg. C. The temperature was regulated by means of a "Reichardt's thermo-regulator." They were again weighed (the percentage of moisture evaporated was calculated), and then immediately placed in a fire clay muffle and packed all round with powdered charcoal. A small hole was bored in the asbestos front, to allow the products of combustion to escape. The closed muffle was then inserted in a gas muffle furnace and the gas turned full on. Carbonisation commenced in five minutes, and the products of combustion

ceased to be visible in twenty minutes. The process was complete in forty minutes, when the gas was turned off, and the specimens allowed to cool. They were then removed from the furnace, and again weighed, and the percentage of charcoal ascertained. The following Table 6 shows the total weight of the cubes before being dried, the percentage of moisture evaporated during drying, the weight after being dried, the weight of charcoal produced, and the percentage of charcoal calculated from the dry weight of the wood. All weights are in grains.

TABLE 6.

Name of timber.	Total weight.	Per c. of moisture.	Dry weight.	Wt. Charcoal.	Per c. of Charcoal
Ulabo -	825.58	14.87	702.80	237.40	33.77
Alaga -	596.00	15.92	501.00	105.60	21.07
Kokolio -	482.00	14.73	413.80	115.38	27.88
Madave -	433.00	17.34	369.00	88.80	24.06
Tamanau -	394.36	13.37	341.60	85.88	25.14
Ilimo -	305.00	15.41	258.10	62.65	24.21

This may be considered rapid carbonisation. The temperature was about 700 deg. F.

Percentage of Ash.

The same timbers, in fact, cubes adjoining those treated for charcoal, were prepared in the same manner, and submitted to a similar process, except that the specimens were placed in porcelain crucibles, in an open furnace. The combustion was complete in every case, and the succeeding table gives the amount and percentage of ash obtained:—

TABLE 7.

Name of timber.	Tot. weight wood.	Tot. ash.	Per c. ash.	Colour of ash.
Ulabo	810.36	9.22	1.138	White-yellowish.
Alaga -	587.94	5.77	.997	Pure white.
Kokoilo -	486.02	2.04	.422	White, dirty.
Madave -	427.76	1.37	.319	White yellowish.
Tamanau -	392.81	5.15	1.310	White-yellow tinge.
Ilimo -	309.54	2.85	.922	Brown mousecolour.

Each set of experiments is given in the schedule of details.

From the above two tables (6 and 7) it will be seen what quantity of charcoal and ash can be obtained from any given weight of dry wood, and also the proportion of volatile matter given off during combustion. It must be remembered,

however, that seasoned wood always contains at least 12 per cent. of moisture, so that the volatile matter, apart from the moisture, would be calculated on 88 pounds of dry wood. Take an example, say *Madave*:—100 pounds of ordinary seasoned wood contains 12 pounds of moisture; during carbonisation, this moisture is first driven off, leaving 88 lbs. of dry wood. Now, as *Madave* yields 24 per cent. of charcoal, the weight of charcoal produced from 88 lbs. would be 21 lbs., and the volatile substances would weigh $88-21=67$ lbs.

The percentage of ash contained in the charcoal may also be calculated, the results being interesting in that they enable one to select special fuel for special work. In this series, the charcoal of *Tamanau* contains the greatest quantity of ash, and that of *Madave* the least, thus:—

Madave	-	-	1.3%
Kokoilo	-	-	1.5
Ulabo	-	-	3.3
Ilimo	-	-	3.8
Alaga	-	-	4.7
Tamanau	-	-	5.2

With regard to the burning properties of the woods, *Ulabo* proved to be the most difficult to burn, as was anticipated from the experiments on the burning of splinters.

Conclusion.

The author had intended to make several other tests, but considered it unwise to withhold the matter already collected.

Papua contains a great variety of timber trees, the wood from which is of economic value; it is therefore essential that a botanical survey be undertaken and a thorough investigation be entered upon, in order to prove their usefulness for the great variety of purposes to which timber is applied.

The schedules of details and photographs of fractures will help the reader to appreciate the summaries in the earlier pages.

The author desires to acknowledge the kindly help of Prof. Henry Payne and his assistant, Mr. Taylor, also that of Mr. Donald Clark and his assistant, Mr. G. Frieberg, in the charcoal and ash tests.

Schedule of Details.—Beams.

Letter.	Wt. per cu. ft.	Dimensions.			Breaking Weight.	F.	Weight at Elastic Limit.	Defl. at E.L.	E.	Ult. Defln.
		Span.	Breadth.	Depth.						
<i>Ulabo. Afzelia Bijuga.</i>										
(a)	- 68.5 -	45.71	- 5.86 -	3.82	- 21350 -	17230	- 12200 -	.426	- 2309000	- 1.05
			Good fracture, gave fair warning, fibrous, tough.							
(b)	- 66.4 -	45.71	- 5.85 -	3.65	- 18300 -	16070	- 13600 -	.65	- 2035000	- 1.00
			Good general fracture, gave fair warning, fibrous, tough.							
(c)	- 68.8 -	45.71	- 3.69 -	5.87	- 33400 -	18010	- 22000 -	.402	- 2097000	- 0.80
(d)	- 66.2 -	45.71	- 3.77 -	5.90	- 28000 -	14630	- 21500 -	.405	- 1896000	- 0.65
<i>Tamanau.</i> (No botanical name).										
(a)	- 30.7 -	45.71	- 5.77 -	3.83	- 10200 -	8260	- 6100 -	.429	- 1213000	- 1.10
			Good general fibrous fracture, gave ample warning.							
(b)	- 30.6 -	45.71	- 5.73 -	3.74	- 11300 -	9670	- 6300 -	.48	- 1211000	- 1.30
			Broke suddenly, but good general fracture, fairly fibrous.							
(c)	- 29.6 -	45.71	- 3.87 -	5.67	- 14100 -	7770	- 7300 -	.293	- 977100	- 1.25
(d)	- 30.7 -	45.71	- 3.95 -	5.72	- 16120 -	8550	- 9900 -	.352	- 979700	- 1.20
			Broke suddenly, rather brittle.							
<i>Alaga.</i> Fam. <i>Sapotaceae.</i>										
(a)	- 42.6 -	45.71	- 5.7 -	3.6	- 8780 -	8100	- 5500 -	.396	- 1466000	- 0.85
			Good general fracture, fairly tough, small worm holes in sapwood.							
(b)	- 38.9 -	45.71	- 3.75 -	5.7	- 16800 -	9340	- 11500 -	.32	- 1460000	- 1.45
			Good general rather fibrous fracture.							
(c)	- 45.5 -	45.71	- 3.70 -	5.64	- 17040 -	9930	- 9800 -	.257	- 1782000	- 0.95
			Distinct compression at 16,800 lbs., good fibrous fracture. See <i>Photograph, Plate XV.</i>							
(d)	- 40.4 -	45.71	- 5.70 -	3.75	- 8500 -	7270	- 5500 -	.349	- 1450000	- 0.60
			Broke suddenly, brittle fracture.							

Schedule of Details.—Beams.. Continued.

Letter.	Wt. per cu. ft.	Dimensions.			Breaking Weight.	F.	Weight at Elastic Limit.	Defl. at E.L.	E.	Ult. Defn.
		Span.	Breadth.	Depth.						
<i>Madave. Shorea Dipterocarpacee.</i>										
(a)	- 36.6	- 45.71	- 5.5	- 3.77	- 7550	- 6620	- 5900	- .491	- 1127700	- .70
					Broke suddenly, treble scarf fracture, rather brittle.					
(b)	- 37.7	- 45.71	- 3.77	- 5.53	- 11080	- 6590	- 8900	- .373	- 1035000	- .65
					Broke suddenly, oblique scarf fracture, brittle, some fungus.					
<i>Kokoila. Calophyllum inophyllum.</i>										
(a)	- 41.4	- 45.71	- 5.8	- 3.72	- 4000	- 3410	- 3500	- .486	- 667400	- .50
					Long scarf fracture, very brittle, cross-grained, some worm holes.					
(b)	- 40.1	- 45.71	- 5.9	- 3.7	- 8330	- 7070	- 3000	- .316	- 878600	- .48
(c)	- 40.0	- 45.71	- 3.64	- 5.75	- 8520	- 4930	- 6500	- .333	- 783700	- .50
(d)	- 39.3	- 45.71	- 3.64	- 5.74	- 13100	- 7490	- 7000	- .324	- 869000	- .65
					The latter three broke suddenly, brittle, scarf fractures.					
<i>Ilimo. Order Bignoniaceae.</i>										
(a)	- 31.7	- 45.71	- 5.8	- 3.8	- 6800	- 5566	- 5000	- .574	- 758000	- .80
					Good general, rather brittle fracture.					
(b)	- 28.9	- 45.71	- 5.75	- 3.85	- 7260	- 5255	- 5300	- .53	- 844500	- .95
(c)	- 30.8	- 45.71	- 5.80	- 3.75	- 4500	- 3783	- 3400	- .36	- 853000	- .50
					Broke suddenly in tension, then sheared.					
(d)	- 32.2	- 45.71	- 3.8	- 5.7	- 7800	- 4340	- 6400	- .355	- 728200	- .60
					Good general fracture, but brittle.					

DETAILS OF COMPRESSION TESTS.

No.	Length (in.)	Breadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in
<i>Ulabo.</i>						
(a)	- 20	- 2.90	- 2.90	- 8.41	- 70400	- 8370
Fracture wedge-shaped, with a tendency to fail in several places; fibres turned over in the direction of the annual rings.						
(b)	- 14	- 2.93	- 2.93	- 8.58	- 91300	- 10640
Fibres turned over in the direction of the annual rings, wedge-shaped fracture on two sides.						
(c)	- 20	- 2.86	- 2.86	- 8.18	- 71800	- 8780
Fibres turned over in direction of rings, then sheared.						
(d)	- 20	- 2.86	- 2.86	- 8.18	- 84300	- 10300
Same as (c)., one side wedge-shaped.						

Tamanau.

(a)	-	20	-	2.85	-	2.85	-	8.12	-	42300	-	5210
Fibres turned over in direction of annual rings.												
(b)	-	20	-	2.85	-	2.85	-	8.12	-	44000	-	5420
(c)	-	20	-	2.85	-	2.85	-	8.12	-	41600	-	5120
Fibres turned over as above, then the specimen bent at a right angle to form a long column and split down.												
(d)	-	20	-	2.85	-	2.85	-	8.12	-	44800	-	5530
Same as c., but bent at right angles to annual rings.												

Alaya.

(a)	-	20	-	2.85	-	2.85	-	8.12	-	47000	-	5780
Fibres crushed at each end, then one end turned over as a long column in the direction of the annual rings.												
(b)	-	20	-	2.84	-	2.84	-	8065	-	50500	-	6260
Fibres crushed in the direction of the annual rings.												
(c)	-	20	-	2.85	-	2.85	-	8.12	-	57500	-	7080
(d)	-	20	-	2.82	-	2.82	-	7.95	-	42200	-	5310
Broke suddenly along seasoning crack, by shear.												

Madure.

(a) - 20 - 2.85 - 2.85 - 8.12 - 46200 - 5750
Fibres turned over in the direction of the annual rings.

(b) - 20 - 2.83 - 2.83 - 8.009 - 46200 - 5770
Fibres commenced to turn over, then it sheared suddenly.
(See Photograph, Plate 19).

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
<i>Kokoilo.</i>						
(a)	- 20	- 2.85	- 2.85	- 8.12	- 36300	- 4470
Fibres commenced to crush, then specimen began to bend until it sheared suddenly.						
(b)	- 20	- 2.85	- 2.85	- 8.12	- 39400	- 4850
First bent considerably as long column, fibres crushed and tension side fractured.						
(c)	- 20	- 2.85	- 2.85	- 8.12	- 36200	- 4410
Fibres first commenced to turn over, then sheared obliquely as in a., but shorter.						
(d)	- 20	- 2.85	- 2.85	- 8.12	- 44000	- 5450
Fibres crushed, then bent as long column						

Ilimo.

(a)	- 20	- 3	- 3	- 9	- 30700	- 3410
Fibres crushed, then broke as long column at right angles to the annual rings.						
(b)	- 20	- 2.85	- 2.85	- 8.12	- 27000	- 3320
(c)	- 20	- 2.85	- 2.85	- 8.12	- 31000	- 3820
(d)	- 20	- 2.85	- 2.85	- 8.12	- 32200	- 3960
In the last three, the fibres crushed at end in direction of rings.						

DETAILS OF TENSION TESTS.

All the tension specimens were 0.76 inch. diam. the area being 0.4536 sq. inches.

Ulabo.

No.	B. wt.	B. wt. sq. in.	Remarks.
(a)	- 9720	- 21430	- Oblique fracture, partial shear, brittle
(b)	- 5000	- 11020	- General fracture, rather brittle
(c)	- 7600	- 16750	- Long scarf fracture
(d)	- 6260	- 13800	- Long scarf fracture

Tamanau.

(a)	- 4380	- 9650	- Fairly general fracture, inclined to
(b)	- 5170	- 11400	- Brittle fracture [brittleness
(c)	- 5180	- 11420	- Long scarf fracture, partial shear.
(d)	- 4860	- 10710	- Fairly fibrous fracture, partial shear

No.	B. wt.	B. wt. sq. in.	Remarks.
<i>Alaga.</i>			
(a)	- 3820	- 8420	- Scarf, cross-gained fracture.
(b)	- 9300	- 20500	- Good fibrous fracture, straight-grained
(c)	- 10300	- 22700	- Good fibrous fracture, fairly straight grained
(d)	- 2900	- 6390	- Short scarf fracture, cross grained

Maduve.

(a)	- 2530	- 5580	- Scarf fracture, cross grained
(b)	- 2350	- 5180	- Scarf fracture, cross grained

Kokoilo.

(a)	- 2530	- 5580	- Short brittle fracture
(b)	- 1300	- 2860	- Short brittle fracture
(c)	- 1650	- 3640	- Short brittle fracture
(d)	- 3520	- 7760	- Short brittle fracture, small worm hole

Ilimo.

(a)	- 2760	- 6080	- Scarf cross grained fracture
(c)	- 2000	- 4410	- Brittle fracture
(d)	- 2500	- 5570	- Brittle fracture

DETAILS OF SHEARING TESTS.

No.	Depth.	Dimensions. B'dth.	Area.	Breaking weight.	B. wt. per sq. in.
<i>Ulabo.</i>					
(a)	- 1.5	- 2.9	- 8.70	- 25250	- 2900
(a)	- "	- "	- "	- 16250	- 1870
(c)	- "	- "	- "	- 29000	- 3330
Parallel to rings.					
(a)	- "	- "	- "	- 13000	- 1490
(a)	- "	- "	- "	- 10000	- 1150
(c)	- "	- "	- "	- 17500	- 2000
Right angles to rings.					

No.	Depth.	Dimensions. B'dth.	Area.	Breaking weight.	B. wt. per sq. in.
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Alaga.

(a)	-	1.5	-	2.8	-	8.40	-	13000	-	1550
(c)	-	"	-	"	-	"	-	14100	-	1860

Parallel to rings.

(b)	-	"	-	"	-	"	-	12100	-	1440
(c)	-	"	-	"	-	"	-	16750	-	2000

Right angles to rings.

Tamanau.

(a)	-	1.5	-	2.9	-	8.70	-	13000	-	1490
(b)	-	"	-	"	-	"	-	6850	-	787
(d)	-	"	-	"	-	"	-	9600	-	1100

Parallel to rings.

(a)	-	"	-	"	-	"	-	8600	-	988
(b)	-	"	-	"	-	"	-	11500	-	1310
(d)	-	"	-	"	-	"	-	7700	-	885

Right angles to rings.

Madave.

(a)	-	1.5	-	2.8	-	8.4	-	15250	-	1820
(a)	-	"	-	"	-	"	-	15250	-	1820

Parallel to rings.

(a)	-	"	-	"	-	"	-	16000	-	1900
(a)	-	"	-	"	-	"	-	14250	-	1700

Right angles to rings.

Kokoilo.

(b)	-	1.5	-	2.8	-	8.4	-	17500	-	2080
(c)	-	"	-	"	-	"	-	12500	-	1490
(d)	-	"	-	2.85	-	8.55	-	17200	-	2000

Parallel to rings.

(b)	-	"	-	2.8	-	8.4	-	19000	-	2260
(c)	-	"	-	2.85	-	8.55	-	18500	-	2150
(d)	-	"	-	"	-	"	-	17750	-	2080

Right angles to rings.

No.	Depth.	Dimensions. B'dth.	Area.	Breaking weight.	B. wt. per sq. in.
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Ilimo.

(b)	-	1.5	-	2.8	-	8.4	-	6750	-	803
(c)	-	"	-	"	-	"	-	6750	-	803
(d)	-	"	-	"	-	"	-	7000	-	833

Parallel to rings.

(b)	-	"	-	2.9	-	8.70	-	7750	-	890
(c)	-	"	-	2.85	-	8.55	-	8250	-	965
(d)	-	"	-	2.8	-	8.4	-	8500	-	1000

Right angles to rings.

NOTE.—All dimensions are in inches, and all weights are in pounds.

DETAILS OF EXPERIMENTS ON THE PERCENTAGE OF ASH.

No.	Wt. of wood.	Wt. of ash.	Ash per cent.
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Ulabo.

1	-	135.93	-	1.55	-	1.14
2	-	137.00	-	1.47	-	1.073
3	-	125.02	-	1.56	-	1.247
4	-	139.52	-	1.51	-	1.082
5	-	135.63	-	1.52	-	1.120
6	-	137.26	-	1.61	-	1.170

Mean ash per cent. = 1.1386.

Alaya.

1	-	97.45	-	.93	-	.954
2	-	95.90	-	.90	-	.938
3	-	96.01	-	.93	-	.968
4	-	95.31	-	.87	-	.912
5	-	96.34	-	1.13	-	1.172
6	-	96.93	-	1.01	-	1.041

Mean ash per cent. = .9975.

Ilimo.

1	-	51.93	-	.57	-	1.111
2	-	49.30	-	.42	-	.851
3	-	50.60	-	.50	-	.988
4	-	51.38	-	.44	-	.856
5	-	57.17	-	.51	-	.892
6	-	49.16	-	.41	-	.834

Mean ash per cent. = .922.

No.		Wt. of wood.		Wt. of ash.		Ash per cent.
<i>Madave.</i>						
1	-	71.07	-	.22	-	.309
2	-	71.30	-	.23	-	.322
3	-	73.43	-	.23	-	.313
4	-	73.72	-	.25	-	.339
5	-	68.36	-	.22	-	.321
6	-	69.88	-	.22	-	.314

Mean ash per cent. = .3198.

<i>Kokoilo.</i>						
	1	-	86.14	-	.31	.358
	2	-	83.48	-	.32	.385
	3	-	86.24	-	.34	.394
	4	-	80.77	-	.31	.383
	5	-	70.65	-	.35	.495
	6	-	78.74	-	.41	.520

Mean ash per cent. = .442.

<i>Tamanau.</i>						
	1	-	66.38	-	.90	1.355
	2	-	64.70	-	.84	1.298
	3	-	65.34	-	.88	1.346
	4	-	65.02	-	.84	1.290
	5	-	65.15	-	.81	1.243
	6	-	66.22	-	.88	1.329

Mean ash per cent. = 1.310.

APPENDIX, 26TH JUNE, 1911.

Subsequently to the paper being read, the calorific power of the charcoal was ascertained. The experiments were carried out with the latest form of the "Berthelot-Mahler-Krocker Bomb Calorimeter," the formula used being that supplied with the apparatus. The equivalent of the calorimeter was first ascertained by burning known weights of naphthalene, and the constant thus obtained was used throughout the experiments.

